SNS COLLEGE OF ALLIED HEALTH SCIENCES

SNS Kalvi Nagar, Coimbatore - 35

Affiliated to Dr MGR Medical University, Chennai

DEPARTMENT OF PHYSICIAN ASSISTANT

COURSE NAME : BIOCHEMISTRY

TOPIC : CARBOHYDRATES

INTRODUCTION

- Carbohydrates, or carbs, are sugar molecules.
- Along with proteins and fats, carbohydrates are one of three main nutrients found in foods and drinks.
- Our body breaks down carbohydrates into glucose.
- Glucose, or blood sugar, is the main source of energy for your body's cells, tissues, and organs.
- Glucose can be used immediately or stored in the liver and muscles for later use.

3 types of carbohydrates:

- **Sugars:** They are also called simple carbohydrates, they can be added to foods, such as the sugar in candy, desserts, processed foods, and regular soda and are found naturally in fruits, vegetables, and milk.
- **Starches:** They are complex carbohydrates, which are made of lots of simple sugars strung together.
- Our body needs to break starches down into sugars to use them for energy.
- Starches include bread, cereal, and pasta and also include certain vegetables, like potatoes, peas, and corn.
- **Fiber:** It is also a complex carbohydrate. Diets high in fiber have other health benefits.
- They may help prevent stomach or intestinal problems, such as constipation. They may also help lower cholesterol and blood sugar.
- Fiber is found in many foods that come from plants, including fruits, vegetables, nuts, seeds, beans, and whole grains.

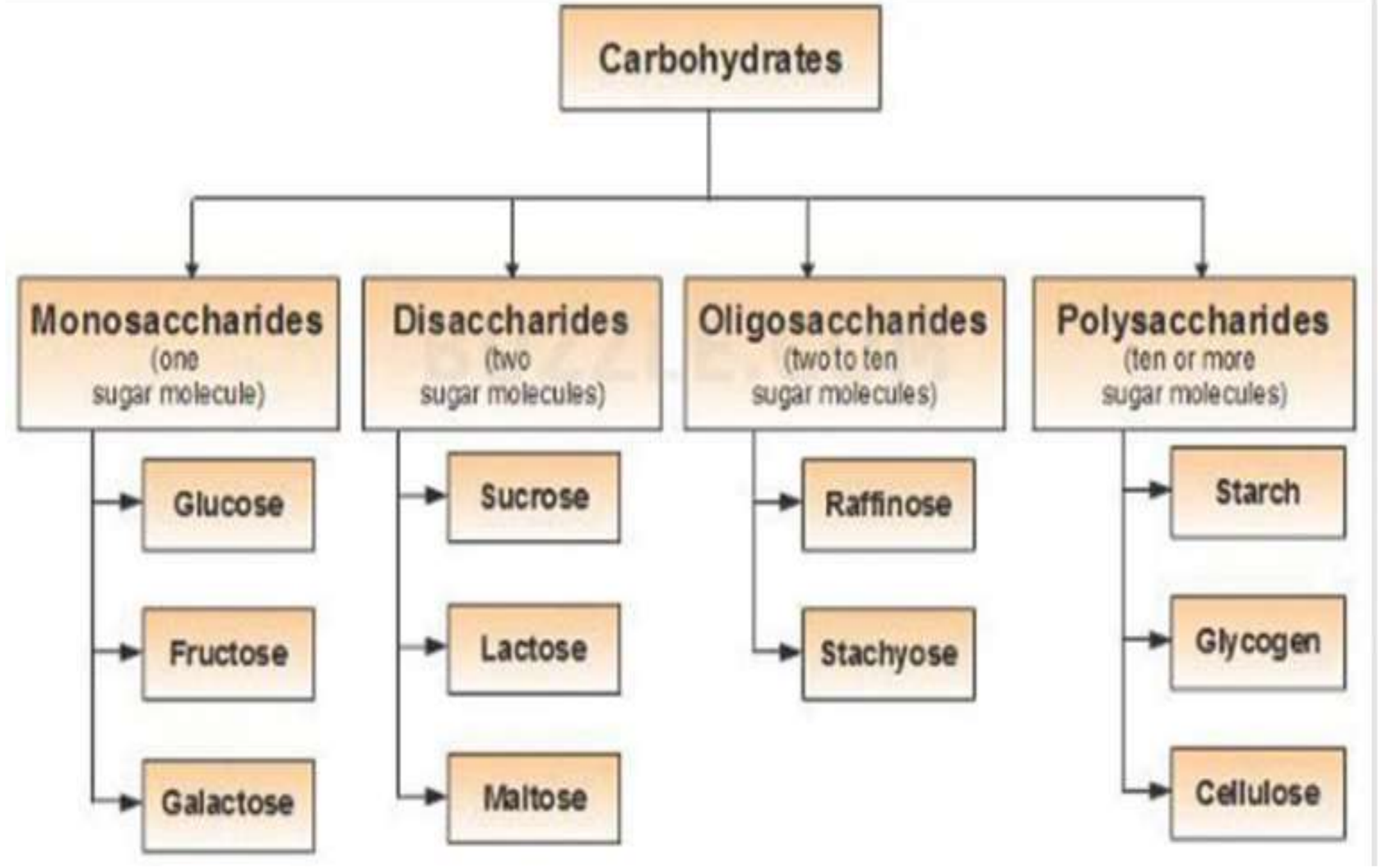
- Common foods with carbohydrates include:

- Grains, such as bread, noodles, pasta, crackers, cereals, and rice
- Fruits, such as apples, bananas, berries, mangoes, melons, and oranges
- Dairy products, such as milk and yogurt
- Legumes, including dried beans, lentils, and peas
- Snack foods and sweets, such as cakes, cookies, candy, and other desserts
- Juices, regular sodas, fruit drinks, sports drinks, and energy drinks that contain sugar
- Starchy vegetables, such as potatoes, corn, and peas

Structure of Carbohydrates

- Carbohydrates consist of carbon, hydrogen, and oxygen.
- The general empirical structure for carbohydrates is (CH20)n.
- They are organic compounds organized in the form of aldehydes or ketones with multiple hydroxyl groups coming off the carbon chain.
- The carbohydrates can be structurally represented in any of the three forms:
- Open chain structure
- Hemi-acetal structure
- Haworth structure
- **Open chain structure -** It is the long straight-chain form of carbohydrates.
- **Hemi-acetal structure -** Here the 1st carbon of the glucose condenses with the -OH group of the 5th carbon to form a ring structure.
- **Haworth structure -** It is the presence of the pyranose ring structure.

Classification of Carbohydrates



Monosaccharides

- The building blocks of all carbohydrates are simple sugars called monosaccharides.
- A monosaccharide can be a polyhydroxy aldehyde (aldose) or a polyhydroxy ketone (ketose).
- Monosaccharide carbohydrates are those carbohydrates that cannot be hydrolyzed further to give simpler units of polyhydroxy aldehyde or ketone.
- If a monosaccharide contains an aldehyde group then it is called aldose and on the other hand, if it contains a keto group then it is called a ketose.
- One of the most important monosaccharides is glucose. The two commonly used methods for the preparation of glucose are
- **From Sucrose**: If sucrose is boiled With dilute acid in an alcoholic solution then we Obtain glucose and fructose.
- **From Starch**: We can obtain glucose by hydrolysis of starch and by boiling it with dilute H2S04 at 393K under elevated pressure.

Disaccharides

- On hydrolysis, disaccharides yield two molecules of either the same or different monosaccharides.
- The two monosaccharide units are joined by oxide linkage which is formed by the loss of water molecule and this linkage is called glycosidic linkage.
- Sucrose is one of the most common disaccharides which on hydrolysis gives glucose and fructose.
- Maltose and Lactose (also known as milk sugar) are the other two important disaccharides.
- In maltose, there are two a-D-glucose and in lactose, there are P-D-glucose which are connected by an oxide bond.

Polysaccharides

- Polysaccharides contain long monosaccharide units joined together by glycosidic linkage.
- Most of them act as food storage for e.g. Starch.
- Starch is the main storage polysaccharide for plants.
- It is a polymer of a glucose and consists of two components-Amylose and Amylopectin.
- Cellulose is also one of the polysaccharides that are mostly found in plants.
- It is composed of D- glucose units joined by a glycosidic linkage between Cl of one glucose unit and C4 of the next glucose unit.
- Polysaccharides are also called "glycans".
- Polysaccharides contain more than 10 monosaccharide units and can be hundreds of sugar units in length.
- They yield more than 10 molecules of monosaccharides on hydrolysis.

- Polysaccharides differ from each other in the identity of their recurring monosaccharide units, in the length of their chains, in the types of bond linking units and in the degree of branching.
- They are primarily concerned with two important functions ie. Structural functions and the storage of energy.
- They may be homopolysaccharides/ Homoglycans, containing monosaccharides of the same type (Contains more than 10 same repeating units.)
- Examples are starch, glycogen, cellulose, pectin.
- Heteropolysaccharides/ Heteroglycans i.e., monosaccharides of different types (Contains more than 10 different repeating units.)
- Examples are Hyaluronic acid, Chondroitin.

HOMOPOLYSACCHARIDES

- Homopolysaccharides are chemical compounds that are composed of a single type of monomer
- Composed of the same repeating unit
- Single type of monosaccharide is involved in the formation
- Have simple structures when cornpared to heteropolysaccharides

HETEROPOLYSACCHARIDES

- Heteropolysaccharides are polysaccharides made out of two or more different monosaccharides
- Composed Of different repeating units
- Different types of monosaccharides are
- involved in the formation
- Have complex structures

Oligosaccharides

- Oligosaccharides are compound sugars that yield 2 to 10 molecules of the same or different monosaccharides on hydrolysis.
- The monosaccharide units are joined by glycosidic linkage.
- Based on the number of monosaccharide units, it is further classified as a disaccharide, trisaccharide, tetrasaccharide, etc.
- Oligosaccharides yielding 2 molecules of monosaccharides on hydrolysis is known as a disaccharide, and the ones yielding 3 or 4 monosaccharides are known as trisaccharides and tetrasaccharides respectively, and so on.

Examples: Disaccharides include sucrose, lactose, maltose, etc.

Trisaccharides are Raffinose, Rabinose.

Functions of Carbohydrates

- Carbohydrates are widely distributed molecules in plant and animal tissues.
- In plants and arthropods, carbohydrates from the skeletal structures, they also serve as food reserves in plants and animals.
- They are important energy sources required for various metabolic activities, the energy is derived by oxidation.

Some of their major functions include

- Living organisms use carbohydrates as accessible energy to fuel cellular reactions.
- They are the most abundant dietary source of energy (4kcal/gram) for all living beings.
- Carbohydrates along with being the chief energy source, in many animals, are instant sources of energy.
- Glucose is broken down by glycolysis/ Kreb's cycle to yield ATP, it serve as energy stores, fuels, and metabolic intermediates.
- It is stored as glycogen in animals and starch in plants.
- Stored carbohydrates act as an energy source instead of proteins.

- They form structural and protective components, like in the cell wall of plants and microorganisms.
- Structural elements in the cell walls of bacteria (peptidoglycan or murein), plants (cellulose), and animals (chitin).
- Carbohydrates are intermediates in the biosynthesis of fats and proteins aid in the regulation of nerve tissue and is the energy source for the brain.
- Carbohydrates get associated with lipids and proteins to form surface antigens, receptor molecules, vitamins, and antibiotics.
- Formation of the structural framework of RNA and DNA (ribonucleic acid and deoxyribonucleic acid),
- They are linked to many proteins and lipids, Such linked carbohydrates are important in cell- cell communication and in interactions between cells and other elements in the cellular environment.
- In animals, they are an important constituent of connective tissues.
- Also, they help in the modulation of the immune system,

Properties of Monosaccharides

- Most monosaccharides have a sweet taste (fructose is sweetest; 73% sweeter than sucrose),
- They are solids at room temperature.
- They are extremely soluble in water
- Despite their high molecular weights, the presence of large numbers of OH groups makes the monosaccharides much more water-soluble than most molecules of similar molecular weight
- Glucose can dissolve in minute amounts of water to make a syrup (1 g/ 1 ml H20).

Physical Properties of Carbohydrates

- **Stereoisomerism -** Compound shaving the same structural formula but they differ in spatial configuration.
- Example: Glucose has two isomers with respect to the penultimate carbon atom. They are D-glucose and I-glucose.
- **Optical Activity**-It is the rotation of plane-polarized light forming (+) glucose and (-) glucose.
- **Diastereo isomers** –It is the configurational changes with regard to C2, C3, or C4 in glucose.
- Example: Mannose, galactose.
- **Annomerism** -It is the spatial configuration with respect to the first carbon atom in aldoses and the second carbon atom in ketoses.

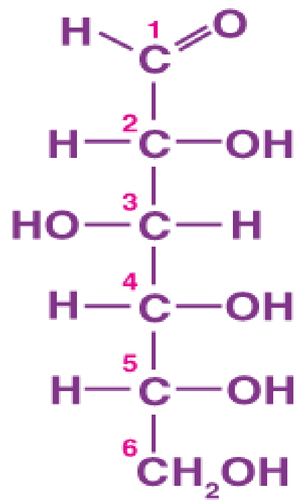
Chemical Properties of Carbohydrates

- **Osazone formation:**
- Osazone are carbohydrate derivatives when sugars are reacted with an excess of phenylhydrazine. eg. Glucosazone
- **Benedict's test:** Reducing sugars when heated in the presence of an alkali gets converted to powerful reducing species known as enediols.
- When Benedict's reagent solution and reducing sugars are heated together, the solution changes its color to orange-red/ brick red.
- **Oxidation**: Monosaccharides are reducing sugars if their carbonyl groups oxidize to give carboxylic acids. In Benedict's test, D-glucose is oxidized to D-gluconic acid thus, glucose is considered a reducing sugar.
- **Reduction to alcohols**: The groups in open-chain forms of carbohydrates can be reduced to alcohols by sodium borohydride, NaBH4, or catalytic hydrogenation (H2, Ni, Et0H/H20). The products are known as "alditols".

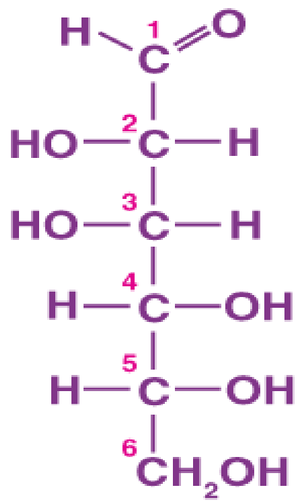
Glucose

- Glucose is also called aldohexose and dextrose and is abundant on earth.
- Glucose is named as D (+)-glucose, D represents the configuration whereas (+) represents the dextrorotatory nature of the molecule.
- The ring structure of glucose can explain many properties of glucose which cannot be figured by open- chain structure.
- The two cyclic structures differ in the configuration of the hydroxyl group at C1 called anomeric carbon.
- Such isomers i.e. α and β form are known as anomers.
- The cyclic structure is also called pyranose structure due to its analogy with pyran.

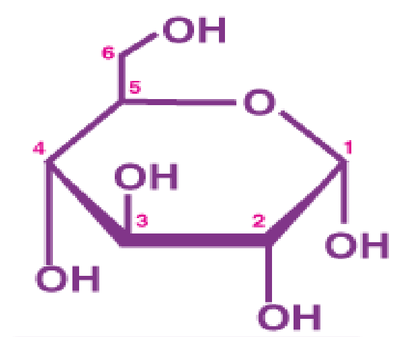
The cyclic structure of glucose is given below:



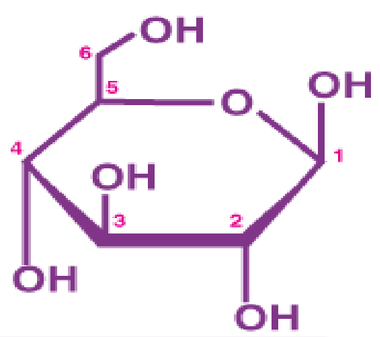
D Glucose



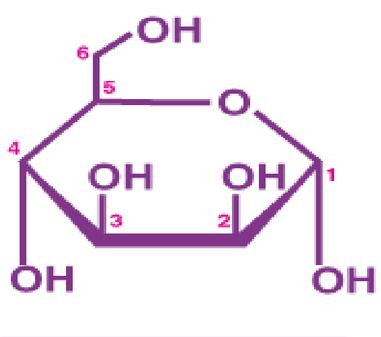
D Mannose



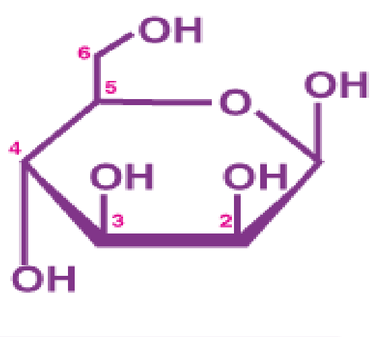
α D Glucose



β D Glucose



α D Mannose

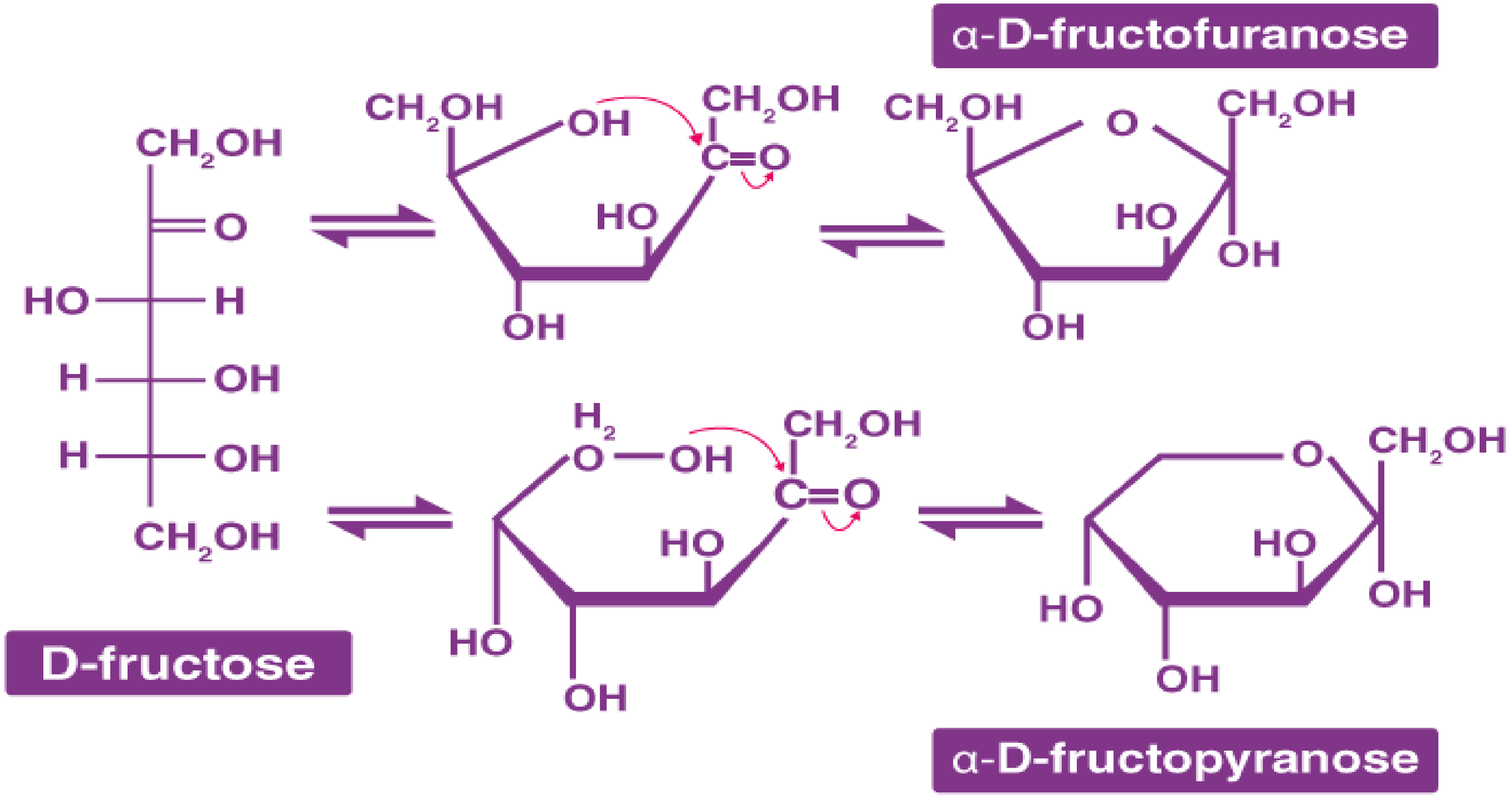


β D Mannose

Fructose

- It is an important ketohexose.
- The molecular formula of fructose is C6H1206 and contains a ketonic functional group at carbon number 2 and has six carbon atoms in a straight chain.
- The ring member of fructose is in analogy to the compound Furan and is named furanose.

The cyclic structure of fructose is shown below:

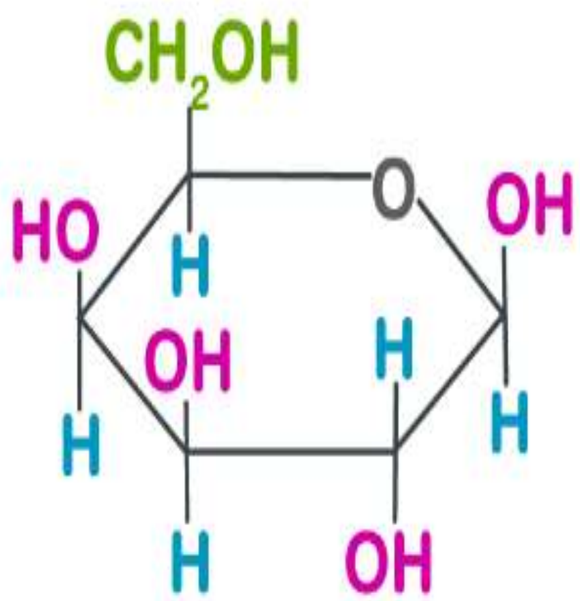


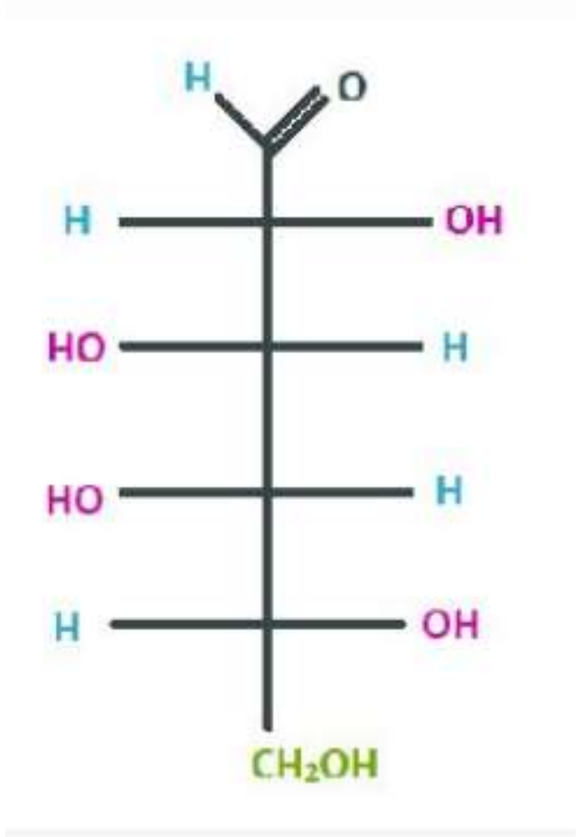
Galactose

- Galactose is a simple sugar belonging to simple carbohydrates which occurs in D-form in lactose.
- It is an odourless white solid
- The molecular formula of galactose is $C_6H_{12}O_6$.
- Galactose is a monosaccharide and epimer of glucose.
- Most of the galactose ingested by humans gets converted to glucose.
- Galactose binds to glucose to make lactose, to lipids to make glycolipids and to proteins to make glycoproteins.

Structure of Galactose

Galactose can exist in open-chain as well as cyclic form.
The chain form of galactose has a similar pattern like glucose.





Properties of Galactose

IUPAC name	(3R,4S,5R,6R)-6-(hydroxymethyl)oxane-2,3,4,5-tetrol
Molecular formula	$C_6H_{12}O_6$
Molecular mass	180.156 g/mol
Density	1.5 $g.cm^{-3}$
Melting point	168-170℃

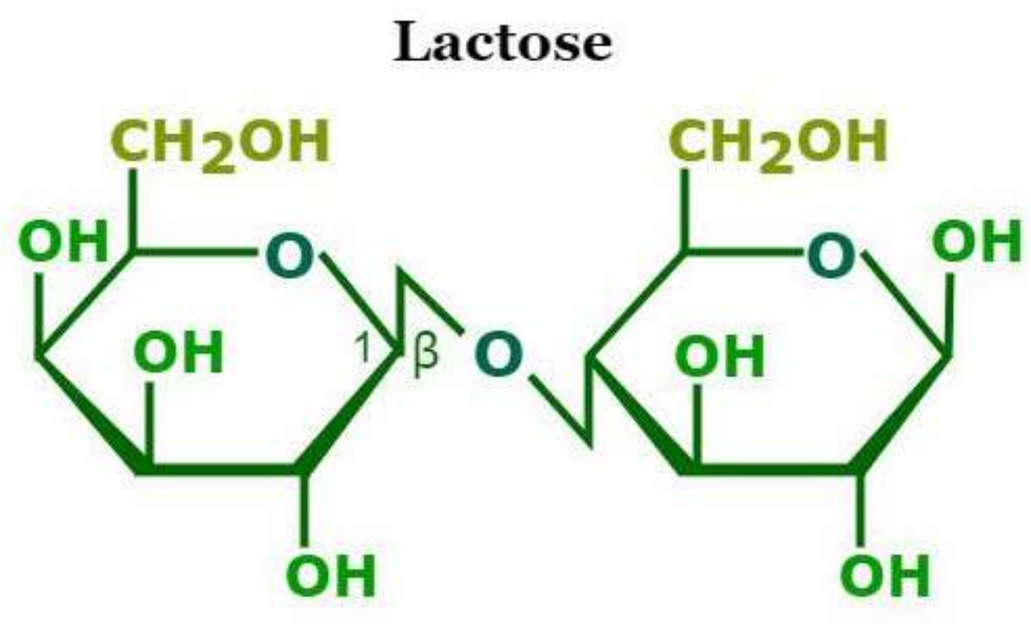
Lactose

- Lactose is a type of carbohydrate that is also called milk sugar and lactobiose.
- It is a disaccharide that is synthesized from galactose and glucose subunits.
- The “lactase” enzyme breaks lactose into glucose and galactose when it is absorbed in the intestine.
- It is used in the food industry, bacterial identification, and pharmaceutical industry, and is also used as a nutrient.

- The molecular formula of lactose is $C_{12}H_{22}O_{11}$, i.e., it is composed of 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms.
- It is a white solid that has a mild sweet taste.
- It is soluble in water and is a non-hygroscopic solid.
- Milk contains around 2-8% lactose (by mass).
- Lactose is found in the mammary glands of all mammals, and a very small amount of lactose can be found in dairy products like yogurt and cheese.
- It is less sweet when compared to sucrose.

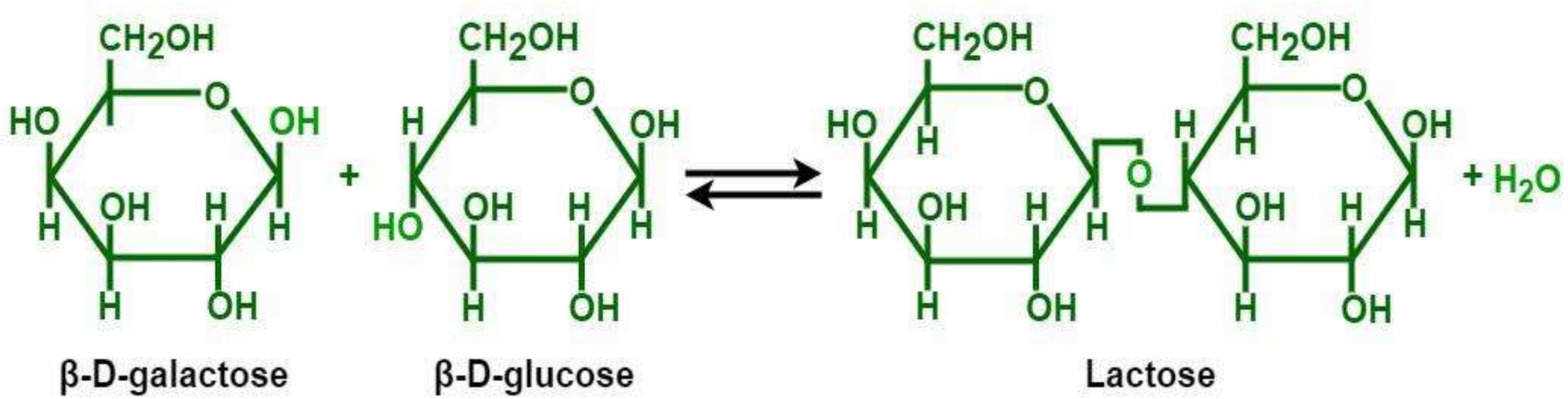
Structure of Lactose

- Lactose is a disaccharide sugar that is formed by the β-1→4 glycosidic linkage of β-D-glucose and β-D-galactose.



Preparation of Lactose

- Lactose can be produced from β-D-glucose and β-D-galactose.



- Industrially, lactose is prepared from whey permeate, where whey is comprised of 6.5% solids, of which 4.8% is lactose, which is crystallized and purified further. It can also be extracted by diluting whey with ethanol.

Physical Properties of Lactose

Chemical formula	$C_{12}H_{22}O_{11}$
Molar mass	342.297 g/mol
Appearance	White solid
Odor	Odorless
Taste	Sweet
Density	1.525 g/cm^3
Melting point	252°C (anhydrous) 202°C (monohydrate)
Solubility	Soluble in water, very slightly soluble in alcohol, insoluble in ether and chloroform

Chemical Properties of Lactose

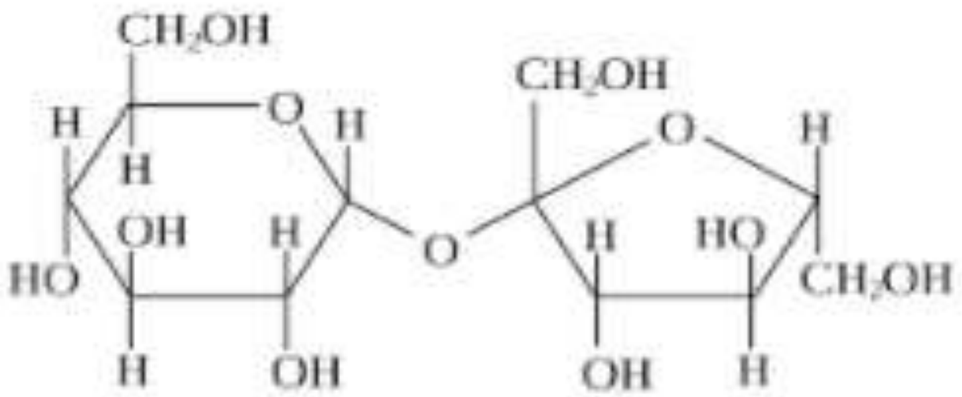
- Lactose on hydrolysis with 2% H_2SO_4 yields 1 mole of D-glucose and 1 mole of D-galactose.
- **$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6$ (glucose) + $C_6H_{12}O_6$ (galactose)**
- Polyhydric alcohol named lactitol is produced by the catalytic hydrogenation of lactose.
- Lactose undergoes hydrogenation in the presence of a Raney-Nickel catalyst, resulting in the formation of lactitol.
- Lactose is isomerized in an alkaline solution to produce Lactulose.
- The molar mass of Lactose is 342.297 g/mol.

Sucrose

- Sucrose is a molecule composed of two monosaccharides, namely glucose and fructose.
- Sucrose is ***commonly referred to as table sugar or cane sugar***.
- **William Miller, an English chemist, coined the word sucrose in the year 1857.**
- It is widely used as a sweetener in food.
- $C_{12}H_{22}O_{11}$ can be obtained from sugar beets or sugar canes, but it must be refined to be fit for human consumption.
- Refined sucrose (or sugar) is a popular ingredient in many food recipes because of its sweet taste.

Structure of Sucrose

- Sucrose has a monoclinic crystal structure and is quite soluble in water.
- This non-reducing disaccharide has a chemical formula of $C_{12}H_{22}O_{11}$.
- In a $C_{12}H_{22}O_{11}$ molecule, the fructose and glucose molecules are connected via a glycosidic bond.
- This type of linking of two monosaccharides called glycosidic linkage.
- The structure of a sucrose molecule is illustrated below.

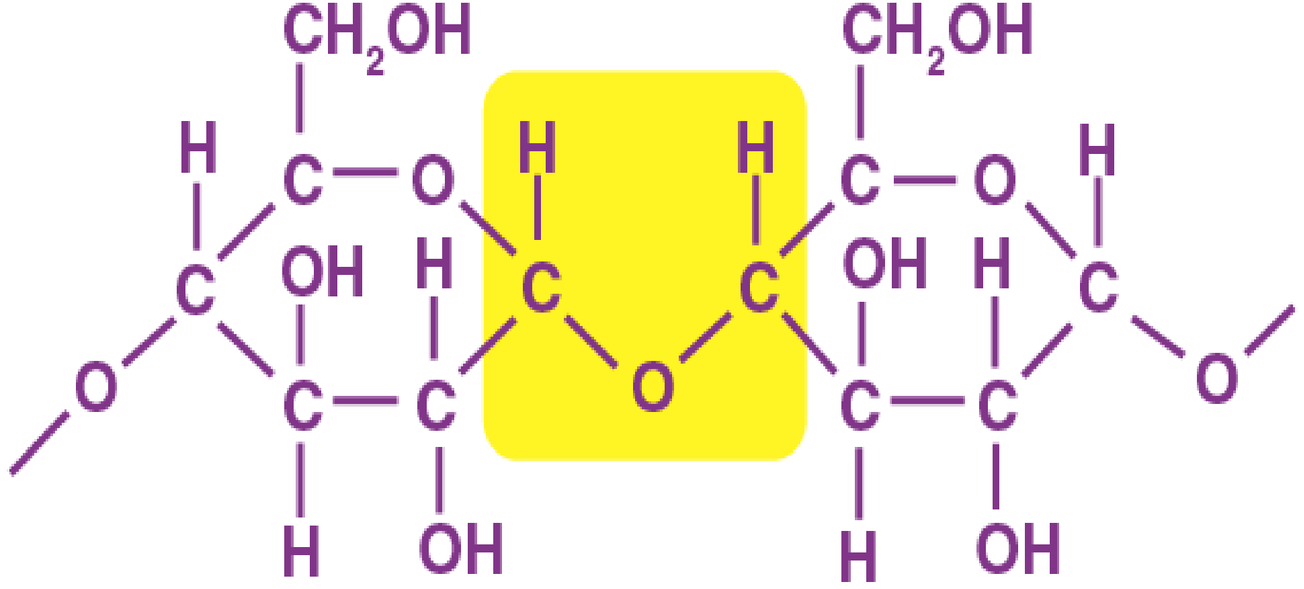


Physical and Chemical Properties of Sucrose

- **Physical**: Sucrose has a monoclinic crystal structure.
- When subjected to high temperatures (over 186°C), this compound decomposes, yielding caramel.
- Its solubility in water at a temperature of 20°C is 203.9g/100mL
- **Chemical**: Sucrose can undergo a combustion reaction to yield CO_2 and water.
- When reacted with chloric acid, this compound yields HCl, carbon dioxide, and water.
- Upon hydrolysis, the glycosidic bond linking the two carbohydrates in a $C_{12}H_{22}O_{11}$ molecule is broken, yielding glucose and fructose.
- Sucrose can be dehydrated with the help of H_2SO_4 (which acts as a catalyst) to give rise to a black solid which is rich in carbon.

Starch

- Starch is a tasteless, fluffy white powder that is insoluble in cold water, alcohol, and other solvents.
- Starch is a polysaccharide made up of 1,4 linkages between glucose monomers.
- The chemical formula of the starch molecule is $(C_6H_{10}O_5)_n$.



- Starch is made up of long chains of sugar molecules that are connected together.
- The linear polymer amylose is the most basic form of starch, while amylopectin is the branched form.
- The primary role of starch is to help plants in storing energy.
- In an animal’s diet, starch is a source of sugar.
- Amylase, an enzyme contained in saliva and the pancreas that breaks down starch for energy, is used by animals to break down starch.

General Properties of Starch

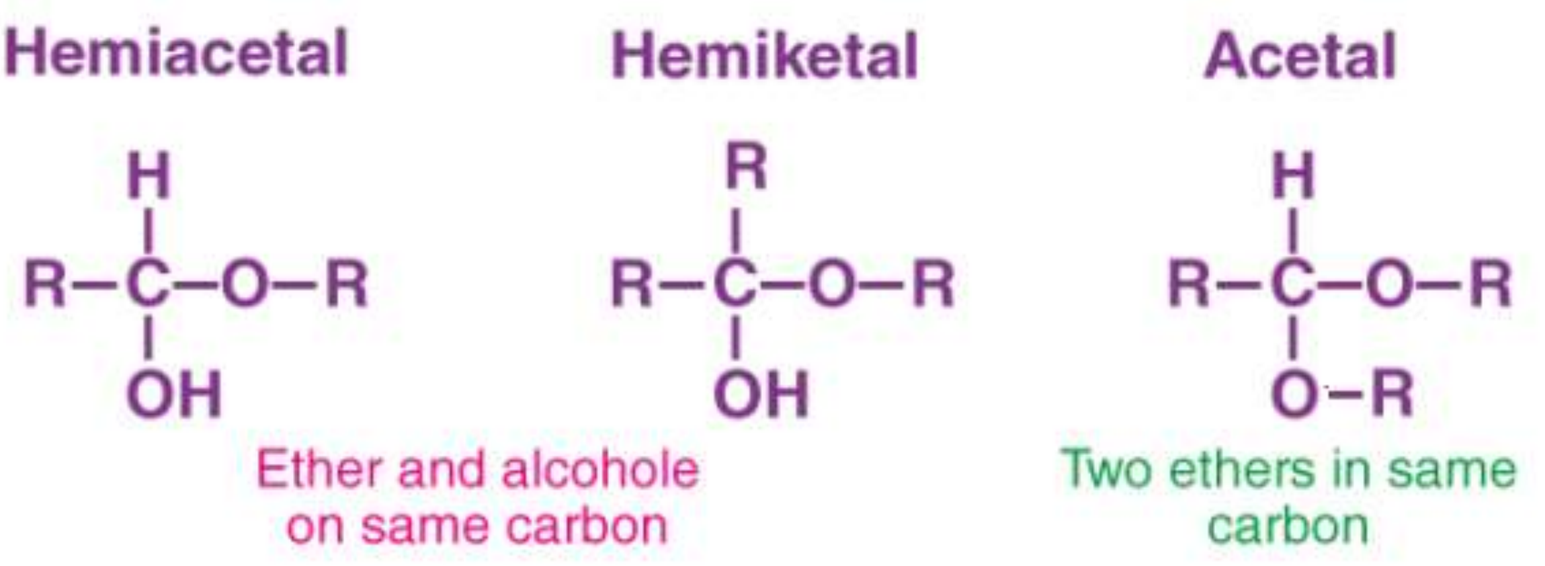
- Starch has a number of properties.
- **Starch as carbohydrate –** Our main source of carbohydrates is starchy foods, which play an important role in a healthy diet. Potatoes, bread, rice, pasta, and cereals are examples of starchy foods.
- **Starch as polysaccharide –** Polysaccharides are a form of biological polymer that is widely used. In living organisms, their role is typically related to the structure or storage. In plants, starch (a polymer of glucose) is present in the forms of amylose and branched amylopectin and is used as a storage polysaccharide.
- **Starch as a non-reducing sugar –** It takes more than one hemiacetal “needle” in a haystack of “acetals” to give a positive sugar-reduction test. As a result, polysaccharides are not classified as reducing sugars. Starch, for example, results in a negative test. Starch and sucrose are both blue, indicating that they are non-reducing sugars.

Glycogen

- Glycogen is a polysaccharide of glucose that serves as a form of energy storage in fungi and animals.
- The polysaccharide structure of glucose shows the primary storage form of glucose in the body.
- Glycogen is made and stored in the cells of liver and muscles that are hydrated with the four parts of water.
- It acts as the secondary long-term energy storage.
- Muscle glycogen is quickly converted into glucose by muscle cells and liver glycogen that converts into glucose for use throughout the body which includes the central nervous system.

Structure of Glycogen

- Glycogen is composed of long polymer chains of glucose units which are bonded with an alpha acetal linkage - Forms by combination of the carbonyl and alcoholic group.
- If the carbonyl group is an aldehyde group i.e (-CHO) also termed as hemiacetal.
- If 2 alkoxy groups are bonded to the same carbon atom, it refers to the acetal group.



- Glycogen refers to the analog of starch which is a glucose polymer that functions as energy storage in plants.
- It has a similar structure to amylopectin which is a component of starch, more extensively branched and compact than starch.
- Every glycogen granule has its core a glycogen in protein because of the glycogen is synthesized.
- In muscles, liver and fat cells glycogen is stored in the hydrated form.
- It is composed of three to four parts of water of glycogen that are associated with 0.45 millimoles of potassium for per gram of glycogen.

Functions of Glycogen

- Liver glycogen acts as glucose reserve that hepatocyte release when there is a need to maintain a normal blood sugar levels.
- There is about 40 kcal in body fluids while hepatic glycogen can provide about 600 kcal after a fasting night.
- Glucose from glycogen stores remains within the cells in skeletal and cardiac muscles and is used as an energy source from muscle work.
- Brain includes a small amount of glycogen in astrocytes.
- It gets accumulated during sleep and is mobilized upon walking.
- Glycogen reserves also assure a moderate degree of protection against hypoglycemia.

THANK YOU